# *Announcements*

- Homework for tomorrow…

  Ch. 32: CQ 9, Probs. 26, 28, & 34

  32.10: 750 A

  32.13: @ a & c: ($2.0 \times 10^{-4}$ T) ihat, @ b: ($2.0 \times 10^{-4}$ T) ihat

  32.14: @ a & c: ($6.7 \times 10^{-5}$ T) khat, @ b: -($2.0 \times 10^{-5}$ T) khat

- Office hours…

  MW 10-11 am

  TR 9-10 am

  F 12-1 pm

- Tutorial Learning Center (TLC) hours:

  MTWR 8-6 pm

  F 8-11 am, 2-5 pm

  Su 1-5 pm

# Chapter 32

## The Magnetic Field

(*The Magnetic Force on a Moving Charge & on a Current-Carrying Wire*)

# Review…

The *B*-field (on axis) of a *current loop* of radius *R* carrying a current *I*, when $z >> R$…

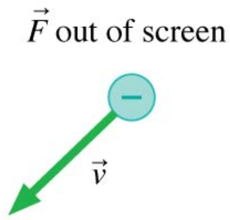
$$\boxed{\vec{B}_{dipole} = \frac{\mu_0}{4\pi}\frac{2\vec{\mu}}{z^3}}$$

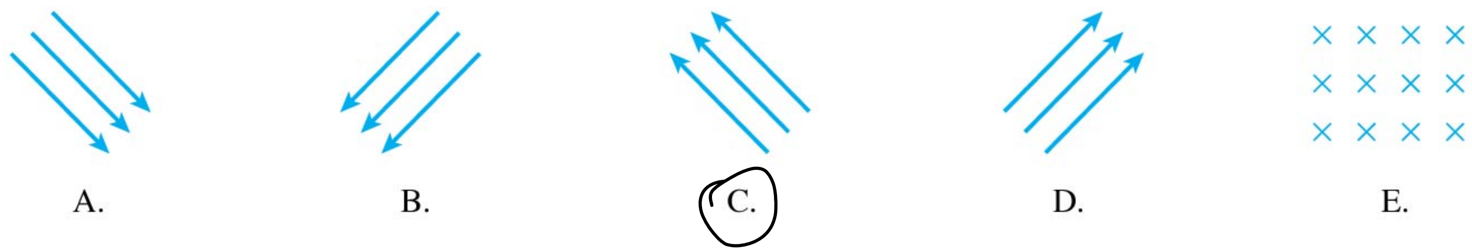
Force on a charged particle with a velocity $v$ in a *B*-field …

$$\boxed{\vec{F}_{on\ q} = q\vec{v} \times \vec{B}}$$

# Quiz Question 1

Which magnetic field causes the observed force?

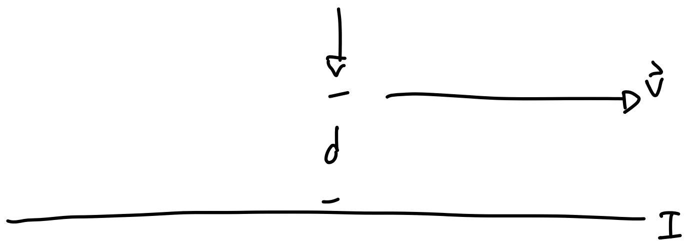


# i.e. 32.10: The magnetic force on an electron

A long wire carries a 10 A current from left to right. An electron 1.0 cm above the wire is traveling to the right at a speed of 1.0 x $10^7$ m/s.

What are the magnitude and the direction of the magnetic force on the electron?




$I = 10A$

$d = 1.0\times10^{-2} m$

$v = 1.0\times10^{7} m/s$

$$\vec{B} = \frac{\mu_0 I}{2\pi d} = \frac{(4\pi\times10^{-7} Tm/A)(10A)}{2\pi(1.0\times10^{-3} m)} = 2.0\times10^{-4}\,T$$

$$\vec{F} = q\vec{v}\times\vec{B}$$

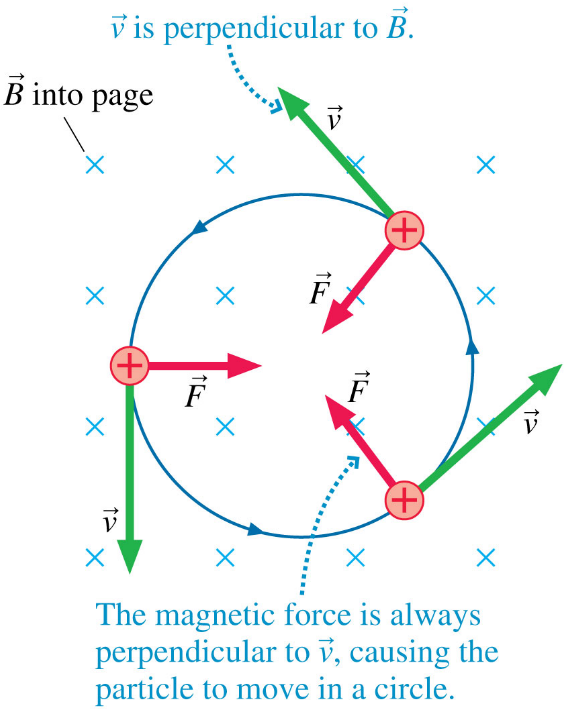
$$F = qvB\sin\alpha = (1.602\times10^{-19} C)(1.0\times10^{7} m/s)(2.0\times10^{-4} T)$$

$$\vec{F} = 3.2\times10^{-16} N\,\hat{j}$$

# Cyclotron Motion

Consider a charged particle moving perpendicular to a *uniform* *B*-field…

- Since *F* is *perpendicular* to *v*, the charge particle undergoes *uniform circular motion.*




The *radius* of the orbit is…

The *frequency* of revolution is…

$$\vec{F}_{net} = m\vec{a}$$

$$\vec{F}_q = q\vec{v} \times \vec{B}$$

$$qvB = m\frac{v^2}{R} \quad \therefore \quad qB = \frac{mv}{R} \quad \left[ r = \frac{mv}{qB} \right]$$

$$v = \frac{2\pi r}{T} \qquad T = \frac{2\pi r}{v}$$

$$\frac{1}{T} = \frac{v}{2\pi r}$$

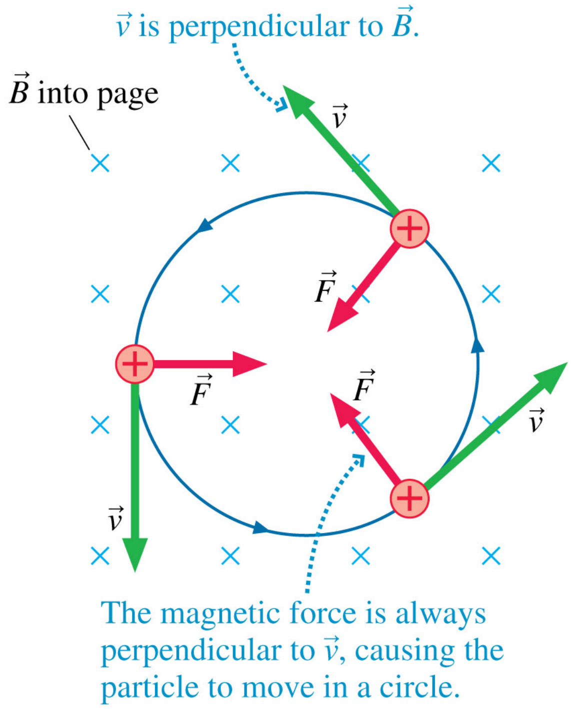
$$f = \frac{1}{T} \qquad \frac{v}{2\pi r} = \frac{v}{2\pi} \cdot \frac{qB}{mv}$$

$$f = \frac{qB}{2\pi m}$$

# Cyclotron Motion

Consider a charged particle moving perpendicular to a *uniform* *B*-field…

- Since *F* is *perpendicular* to *v*, the charge particle undergoes *uniform circular motion*.




The *radius* of the orbit is…

$$\boxed{r_{cyc} = \frac{mv}{qB}}$$

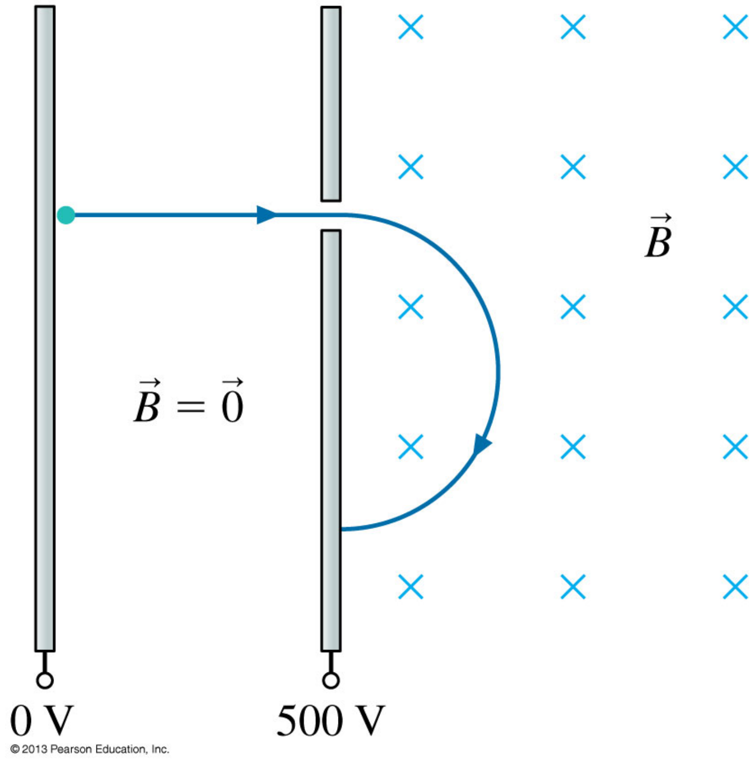
The *frequency* of revolution is…

$$\boxed{f_{cyc} = \frac{qB}{2\pi m}}$$

# i.e. 32.11: The radius of cyclotron motion

In the figure below, an electron is accelerated from rest through a potential difference of 500 V, then injected into a uniform *B*-field. Once in the *B*-field, it completes half a revolution in 2.0 ns.

What is the *radius* of its orbit?




$q = 1.6\times10^{-19}\,C$

$m = 9.11\times10^{-31}\,kg$

$\Delta V = 500V$

$T = 4.0\times10^{-9}\,s$

$f = \frac{1}{T} = 2.5\times10^{8}\,s^{-1}$

$\cancel{K_0}^{\,0} + U_0 = K_1 + \cancel{U_1}^{\,0}$

$U_0 = K_1$

$q\Delta V = \frac{1}{2}mv^2$

$\sqrt{\frac{2q\Delta V}{m}} = v$

$v = 1.3\times10^{7}\,m/s$

$\frac{2\pi m f}{q} = \vec{B}$

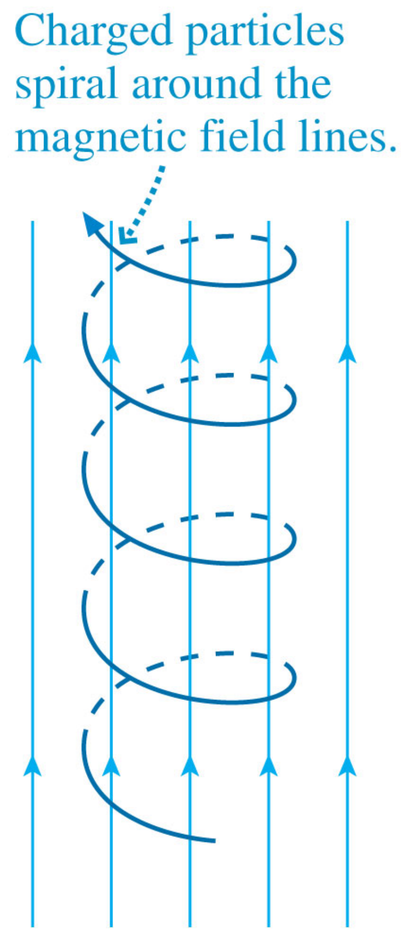
$\vec{B} = 8.9\times10^{-3}\,T$

$r = \frac{mv}{qB}$

$r = 8.3\times10^{-3}\,m$

# *Cyclotron Motion*

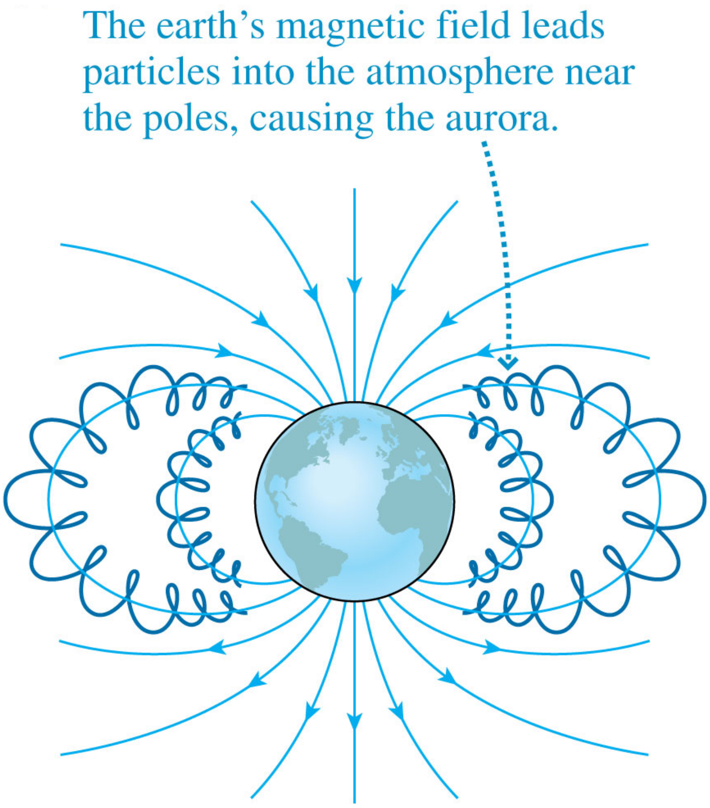
What if $v$ is NOT *perpendicular* to $B$?

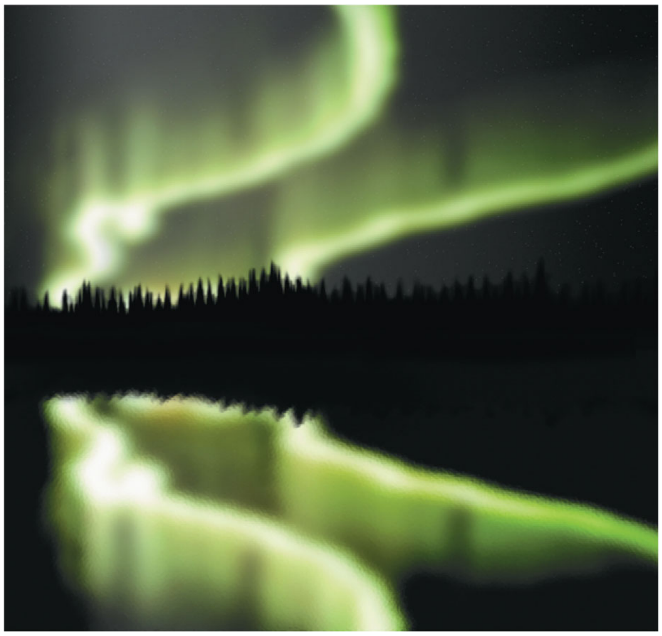



The component of $v$ *parallel* to $B$ is NOT affected by the field.

The component of $v$ *perpendicular* to $B$ determines the *radius* of the *helix*.

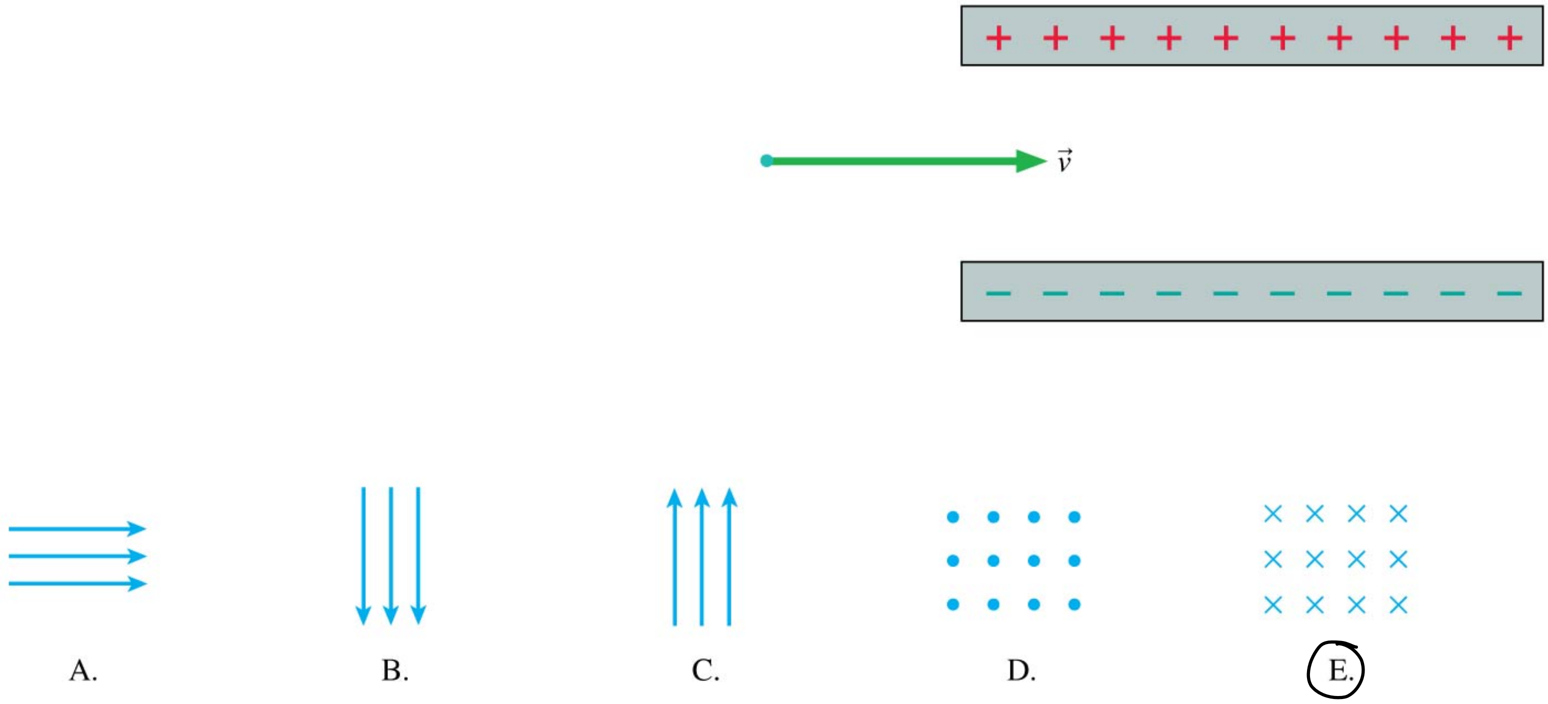
# Aurora


The earth's magnetic field leads particles into the atmosphere near the poles, causing the aurora.



# Quiz Question 2

Which $B$-field (if it's the correct strength) allows the electron to pass through the charged electrodes without being deflected?



# 32.8: Magnetic Forces on Current-Carrying Wires

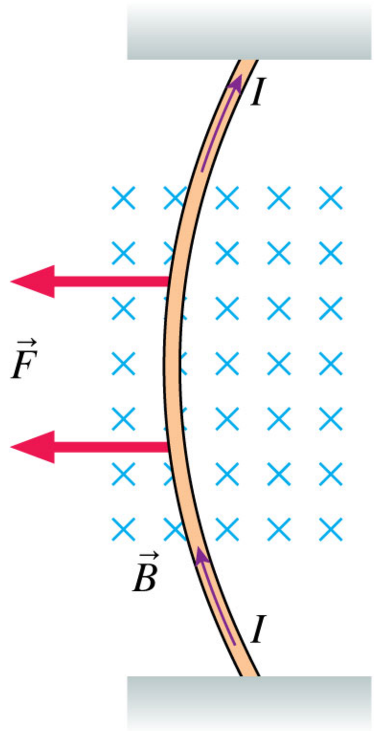
Consider a current-carrying wire *perpendicular* to the *B*-field…

Each charge in the current has a force of magnitude $qvB$ directed to the left.

What is the force on the wire?

$q\vec{v} = I\ell$

$\vec{F} = q\vec{v} \times \vec{B}$



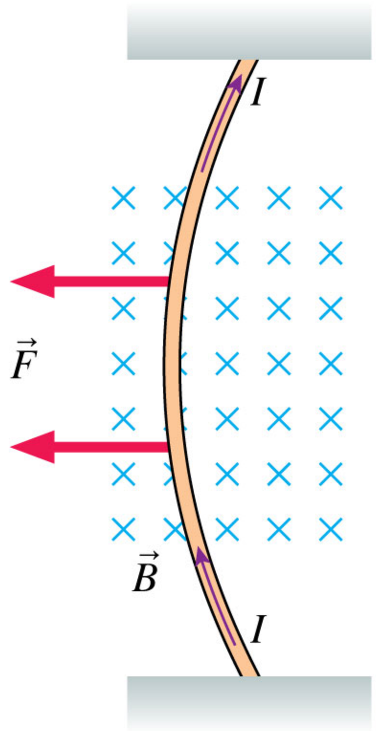
# 32.8: Magnetic Forces on Current-Carrying Wires

Consider a current-carrying wire *perpendicular* to the $B$-field…

Each charge in the current has a force of magnitude $qvB$ directed to the left.

What is the force on the wire?

$$\boxed{\vec{F}_{wire} = I\vec{\ell} \times \vec{B}}$$




*Magnitude:*

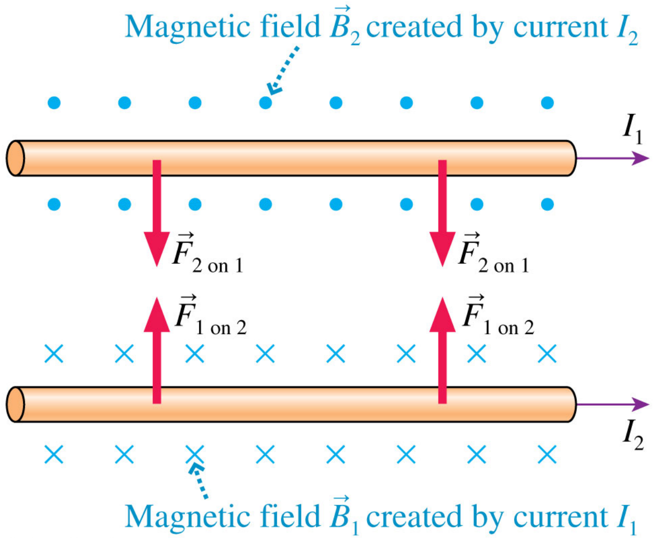
$$F_{wire} = I\ell B \sin\alpha$$

*Direction:*

*RHR*

# *Force Between Two Parallel Wires*

What is the force on $wire_1$ due to $wire_2$?



# Force Between Two Parallel Wires

What is the force on $\text{wire}_1$ due to $\text{wire}_2$?

$$F_{1\ on\ 2} = F_{2\ on\ 1} = \frac{\mu_0 \ell I_1 I_2}{2\pi d}$$